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Comparative Value of Several Fungicides In the Control of Head and Stripe Smuts in Certain Forage Grasses

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Comparative Value of Several Fungicides In the Control of Head and Stripe Smuts In Certain Forage Grasses[1]

George W. Fischer and Jack P. Meiners[2]

INTRODUCTION

Although the literature dealing with the control of cereal smuts is voluminous, comparatively little is known of similar control of grass smuts. Not enough is known of the biology of some of these grass smuts to permit the formulation of control measures. Furthermore, intensive grass cultivation is relatively recent and the practical need for such information has not been strongly felt before. The methods used in the increase and cultivation of grasses, especially the harvesting and threshing processes and the mass planting of species, also tend to increase the prevalence of their smut diseases. In the western states, head smut (*Ustilago bullata* Berk.) and stripe smut [*U. striiformis* (West.) Niessl] are often sufficiently prevalent and destructive on certain cultivated grasses to warrant the general practice of control measures. This is especially true with slender wheatgrass [*Agropyron trachycaulum* (Lk.) Malte], mountain bromegrass (*Bromus marginatus* Nees), rescue grass (*Bromus catharticus* Vahl), meadow bromegrass (*Bromus erectus* Huds.), blue wild-rye (*Elymus glaucus* Buckl.) and Canada wild-rye (*E. canadensis* L.). It has been known for many years that these two smuts are seed-borne and should be controllable by seed treatments. In fact, there are several records which indicate definitely that not only head smut and stripe smut but a few of the other grass smuts as well have been effectively controlled by seed treatment.

McAlpine (15)* reported that in Australia complete control of head smut in *Bromus catharticus* was obtained with the regular copper sulfate or formalin treatments used to control bunt or stinking smut (*Tilletia caries*) of wheat. Gram (8) obtained good

[1] Cooperative investigations of the Department of Plant Pathology, Washington Agricultural Experiment Stations; and the United States Department of Agriculture —the latter represented by the Division of Forage Crops, Bureau of Plant Industry, Soils and Agricultural Engineering and the Soil Conservation Service, Division of Nurseries. Work done under Project No. 451.

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* Numbers in parentheses refer to "Literature Cited," p. 17 .

control of head smut on bromegrasses by sprinkling the seed with 0.5 per cent Germisan, Tillantin C and Agfa. Control of loose smut [*Ustilago avenae* (Pers.) Rostr. (*U. perennans*) Rostr.] of tall oatgrass was obtained by sprinkling the seed with 0.25 per cent formalin or 0.25 per cent Germisan.

Morwood (16) reported excellent control of head smut on *Bromus catharticus* by dusting the seeds with "Abavit B" and Ceresan and also with a 0.2 per cent formalin dip. Simmonds (18) likewise controlled head smut in *Bromus catharticus* through the use of mercurial dusts. He used "Sanogran A, Ceresan U. T. 1875 and cuprous mercurial." He also obtained good results through the use of a formalin dip at 1:320.

Donald (3) obtained complete control of head smut in *Bromus catharticus* through the hot water treatment of the infected seed, immersing them for 100 minutes at a temperature of 120° F. Dusting the seed with an experimental ethyl mercury phosphate dust at 3 ounces per bushel resulted in complete control of the smut, and 95 per cent control was obtained through the use of Ceresan dust. Only 53 per cent control was obtained with copper carbonate dust and 87 per cent control through the use of the regular formalin dip.

Fraser and Scott (6) found formalin solution at 1:320 to be highly effective in the control of head smut in slender wheatgrass. They found that copper carbonate would reduce the amount of smut but would not control it.

Güssow and Conners (10) reported perfect control of head smut of slender wheatgrass by steeping the seed for 5 minutes in 1:320 formalin solution.

Henry, Clay, and Fryer (12) obtained complete control of head smut of slender wheatgrass through the use of three organic mercury dusts containing ethyl mercury phosphate, methyl mercury nitrate, and methyl mercury phosphate, respectively.

Fischer (5), in reporting on some preliminary experiments on the control of head smut in forage grasses, found copper carbonate, copper sulphate, and formaldehyde dust to be ineffective. Two per cent Ceresan and New Improved Ceresan gave excellent control and markedly improved stands. Semesan improved the stands but gave very little smut control. The present paper presents the complete results of subsequent investigations of the effectiveness of treating grass seed with various popular fungicides for the control of head smut and stripe smut of forage grasses under Pacific Northwest conditions.

TABLE 1. TRADE NAME, ACTIVE CONSTITUENT, AND MANUFACTURER OF FUNGICIDES USED IN EXPERIMENTS ON CONTROL OF SMUT IN GRASSES.

Trade Name or Other Designation	Active Constituent	Manufacturer or Source
?	Copper carbonate (52%)	Unknown
?	Copper sulphate (50%)	Unknown
Formacide	Formaldehyde dust	Hammond Paint
Cuprocide	Red cuprous oxide	Rohm & Haas
2% Ceresan	2% ethyl mercury chloride	Dupont-Semesan Co.
New Improved Ceresan	5% ethyl mercury phosphate	Dupont-Semesan Co.
Semesan	30% hydroxymercurichlorophenyl	Dupont-Semesan Co.
"Organic sulphur compound"[a]	Tetramethyl thiuramdisulfide	Dupont-Semesan Co.
Spergon	96% tetrachloro-para-benzoquinine	U. S. Rubber Co.
249A	?[b]	Boyce Thompson Institute
53-501-62	?[b]	Boyce Thompson Institute
582	?[b]	Boyce Thompson Institute
653	?[b]	Boyce Thompson Institute
None	4% phenyl mercury chloride in Bentonite	F. W. Berk & Co.
Dow 9A	75% zinc trichlorophenate	Dow Chemical Co.
Ceresan M	7.7% ethyl mercury p-toluene sulfonanilide	Dupont-Semesan Co.
Crag (531)	100% cadmium copper zinc calcium chromate	Carbide & Carbon Chem. Co.
Tersan	50% thiram (tetramethyl thiuramdisulfide)	Dupont-Semesan Co.
Arasan S. F.	75% thiram (tetramethyl thiuramdisulfide)	Dupont-Semesan Co.
Puratised	Phenyl mercury triethanol ammonium lactate	Niagara Spray Co.
F-800 (Dowicide 2)	2,4,5-trichlorophenol chloroacetate	Dow Chemical Co.
Phygon	2,3, dichlor-1, 4 napthoquinone	U. S. Rubber Co.
Fermate	70% ferbam (ferric dimethyl dithiocarbamate)	Dupont-Semesan Co.

[a] Forerunner of Tersan, Arasan, and Arasan S. F.
[b] Experimental materials; active ingredient unknown.

MATERIALS AND METHODS

All of the fungicides used in these experiments are listed in Table 1 which shows the active ingredients and the manufacturer. The fungicides used include several that have been in common use as cereal seed treatments for many years, as well as a number of newer commercial fungicides, some of which are only in the experimental stage.

The number of species of grasses used in the experiments also varied, but the following were used in one or more of the

tests: *Agropyron trachycaulum, Bromus catharticus, B. erectus, B. marginatus, Elymus canadensis, E. glaucus,* and *Hordeum nodosum* L.

Seed of the grass species was first thoroughly inoculated with aqueous suspensions of chlamydospores of appropriate races of head smut or stripe smut by the partial vacuum method. After the seed had been dried, it was divided into equal lots in grams. Each lot was treated with the different fungicides at dosages and according to methods which will be given individually for each experiment. In all experiments, one lot of inoculated seed was reserved as a control, and in some experiments an uninoculated, untreated check lot was reserved also. After the fungicides were applied, the seed was either planted directly into the field or into wood veneer plant bands in the greenhouse and later transplanted into the field. All treatments were replicated at least three times.

Data were taken on the first heading following planting. Smut percentages were calculated either on the basis of number of heads or the number of plants in a row, as indicated.

RESULTS

Preliminary Experiments on the Control of Head Smut by Seed Treatment

Exploratory experiments were conducted in 1939 and 1940 to test the effect of the seed disinfectants then available against head smut. Inoculated seed of three grasses was treated with six fungicidal dusts as shown in Table 2, sufficient dust being applied to lightly cover the seed. In addition, in 1940, the modified hot water treatment was included, as was 1:320 formaldehyde as a soak for several time intervals. In 1939, the treated seed was planted in rows in the field. In 1940, the treated seed was planted in plant bands in the greenhouse and later transplanted to the field. In both years, three replications of each treatment were used. Data on stand and percentage of smut were computed on the basis of head counts.

The results of these preliminary experiments are given in Table 2. These data show that copper carbonate, copper sulphate, cuprocide, and Formacide, in general, do not give complete control of head smut. New Improved Ceresan and 2 per cent Ceresan, on the other hand, controlled head smut effectively but, except in the case of 2 per cent Ceresan on *A. trachycaulum,* were highly injurious at the dosage used. The modified hot water treatment controlled the smut but reduced stands considerably. The seed

of *Agropyron trachycaulum* and *Elymus canadensis* apparently can withstand long periods of soaking in formaldehyde solution with little or no apparent injury. Thirty minutes or less of soaking did not entirely control head smut, but 1 hour or more did.

The data in Table 2 give some indication that not all of the grass species are equally subject to injury from the treatments, and that the same treatment may effectively control the head smut on one species but not on another.

Effect on the Incidence of Head Smut of Seed Treatment Applied at Different Dosages

In 1941 and 1942, seed treatment experiments were made in order to supplement and perhaps clarify the results obtained from the preliminary experiments. Six fungicidal dusts were selected and used at three or four dosages. The dusts were applied to seven species of grasses which had previously been inoculated with appropriate races of head smut. The fungicides were applied several days before the seed was planted in the nursery. All treatments were replicated three times.

The results of this experiment, presented in Table 3, provide a comparison of the six fungicides used. The most immediately apparent result is the comparative ineffectiveness of copper carbonate, copper sulfate, Formacide, and Semesan in the control of head smut. In substantiation of earlier results, the amount of control varies somewhat with the different grasses used. Thus, with *Bromus catharticus* these four fungicidal dusts were almost totally ineffective. They were only slightly better with *Bromus marginatus* and with *Hordeum nodosum*. With *Elymus canadensis*, however, Semesan at 2, 4, or 6 ounces per bushel appreciably reduced the amount of smut; and copper carbonate dust applied at the rate of 6 ounces per bushel gave good control of smut in *Agropyron trachycaulum*. Formacide resulted in fair smut control on *Elymus glaucus* when applied at 5 or 7 ounces per bushel.

As a further illustration of the general ineffectiveness of copper carbonate, copper sulphate, Formacide, and Semesan in the control of head smut, instances may be noted in the data in Table 3 where a greater percentage of smut actually resulted from treated than from the untreated seed. It is possible that in these instances, while the fungicide did not protect the germinating seeds from smut infection, it did protect them from certain seedling diseases. It has been noticed repeatedly that, in some grass species, seedlings coming from heavily smutted seed seem to be predisposed to attack by soil-borne organisms which often seriously deplete the stands. The fungicides, therefore, may have

TABLE 2. EFFECT OF VARIOUS SEED TREATMENTS ON CONTROL OF HEAD SMUT (*Ustilago bullata*).

Treatment	Agropyron trachycaulum				Elymus canadensis				Hordeum nodosum	
	1939		1940		1939		1940		1939	
	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut
Check	531[a]	9.0	0	0.0	331	78.5	217	35.4	170	84.1
$CuCO_3$ (52%)	578	3.8	123	6.5	521	33.9	90	6.6	216	31.9
$CuSO_4$ (50%)	369	10.8	121	14.0	530	35.2	215	58.6	310	31.9
Formacide	646	7.1	133	0.7	561	44.2	163	38.0	171	32.7
Cuprocide	666	5.5	72	80.5	129	20.1	171	42.1	263	23.1
2% Ceresan	778	0.0	603	0.0	18	0.0	59	3.3	111	0.0
N. I. Ceresan	142	0.0	129	0.0	0	0.0	39	0.0	0	0.0
Mod. Hot Water	------	------	223	0.0	------	------	95	0.0	------	------
Formald. 1-320 5 min.	------	------	734	13.6	------	------	161	13.0	------	------
Formald. 1-320 15 min.	------	------	552	7.0	------	------	177	3.9	------	------
" " 30 min.	------	------	482	4.5	------	------	183	6.0	------	------
" " 1 hr.	------	------	313	0.0	------	------	190	0.0	------	------
" " 1.5 hr.	------	------	513	0.0	------	------	191	0.0	------	------
" " 2 hr.	------	------	251	0.0	------	------	228	0.0	------	------
" " 3 hr.	------	------	342	0.0	------	------	230	0.0	------	------
" " 4 hr.	------	------	395	0.0	------	------	227	0.0	------	------

[a] Average of three replications.

TABLE 3. SUMMARY OF RESULTS OBTAINED WITH 6 FUNGICIDAL DUSTS AT VARIOUS DOSAGES IN CONTROL OF HEAD SMUT (*Ustilago bullata*) ON SEVERAL GRASS SPECIES.

Treatment		Percentage smut produced on indicated species of grasses, and smut races used[a]								
		Race 1	Race 7	Race 2	Race 7	Race 4	Race 7	Race 2	Race 1	
		Agropyron trachycaulum Wm 279[b]	Bromus catharticus F 161	Bromus erectus W 2336	Bromus marginatus W 2133	Elymus canadensis W 2389	Elymus canadensis W 2389	Elymus glaucus W 1841	Hordeum nodosum F 169	Average
		%	%	%	%	%	%	%	%	%
Untreated check		40.3	100.0	18.8	76.1	64.8	78.9	26.2	97.6	62.8
$CuSO_4$	2 oz./bu.	19.2	100.0	19.1	63.1	14.4	57.2	38.8	82.7	49.3
	4 oz./bu.	44.3	100.0	5.6	87.6	27.5	41.7	31.5	82.5	52.8
	6 oz./bu.	69.3	98.3	26.8	88.4	20.1	46.0	32.3	95.7	59.6
$CuCO_3$	2 oz./bu.	27.2	100.0	20.8	74.1	23.1	47.7	22.5	89.9	50.6
	4 oz./bu.	53.1	100.0	20.9	91.6	34.8	78.7	27.2	90.0	62.0
	6 oz./bu.	1.7	100.0	27.9	64.8	27.6	92.5	24.4	51.3	48.7
Formacide	3 oz./bu.	18.5	100.0	60.9	81.2	66.5	91.6	39.6	69.8	66.0
	5 oz./bu.	48.5	100.0	20.8	68.4	72.2	78.9	5.6	55.9	56.2
	7 oz./bu.	49.2	100.0	27.9	82.7	70.3	90.0	5.0	56.8	60.2
Semesan	2 oz./bu.	38.1	95.5	27.6	82.1	6.8	8.3	16.2	66.6	42.6
	4 oz./bu.	80.4	100.0	24.7	40.2	16.4	13.3	12.7	72.6	45.0
	6 oz./bu.	13.8	96.0	28.2	33.8	1.7	0.0	13.8	40.7	28.5
2% Ceresan	2 oz./bu.	0.0	1.8	1.9	2.1	0.0	0.0	0.0	0.0	0.7
	4 oz./bu.	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3
	6 oz./bu.	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.1
N. I. Ceresan	½ oz./bu.	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	1 oz./bu.	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	1½ oz./bu.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2 oz./bu.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	N.S.[c]	0.0

[a] Previously described by Fischer (4).
[b] See footnote a, Table 6.
[c] No stand.

indirectly contributed to a higher percentage of smut in the treated rows than in the check rows by allowing a larger percentage of smut-infected seedlings to escape damping off or seed decay.

In striking contrast to the very poor head smut control resulting from the use of copper sulphate, copper carbonate, Formacide, and Semesan, is the nearly absolute control resulting from the use of 2 per cent Ceresan and New Improved Ceresan. This was even more evident in the field rows than it is in Table 3. The rows representing the other four dusts were blackened with smut

in contrast to the adjacent rows of green smut-free grass arising from seed that had been treated with 2 per cent Ceresan and New Improved Ceresan.

It further appears, from a study of the averages for each treatment as presented in Table 3, that nothing is gained from using higher dosages of 2 per cent Ceresan and New Improved Ceresan. This is also true of the other treatments as well, with the possible exception of Semesan at 6 ounces per bushel.

Effect of Different Post-Treatment Storage Periods on the Control of Smut and on the Viability of the Seed

It is often more convenient to treat grass seed some time in advance of planting. This means that the treated seed must be held in storage, and the question arises concerning the possible effect on viability. To answer this question and to determine the effect of such storage periods on the efficacy of seed treatment for control of head smut, the following experiment was initiated.

Seed of *Elymus canadensis* which had previously been inoculated with either head smut or stripe smut was treated at intervals to result in post-treatment storage periods of 1, 2, 4, 6, and 8 weeks before planting. The following fungicidal dusts were used: Spergon, Semesan, "organic sulphur"[3], and copper carbonate, used at the rates of 2 and 4 ounces per bushel; and New Improved Ceresan at the rates of ½ and 1 ounce per bushel.

Equal quantities of seed (by weight) were planted in 7-foot rows in the field. The data pertaining to head smut were taken on the basis of head counts; for stripe smut, data were taken on the basis of plant counts.

The results for head smut and stripe smut are summarized in Tables 4 and 5, respectively. It is immediately obvious from these data that there were no great differences arising from the various post-treatment storage periods, either with reference to smut control or to stand obtained. Differences are apparent, as before, in the smut control resulting from the several fungicides.

It would appear that stripe smut is more vulnerable to the fungicides used in the above experiment than is head smut. As seen in Table 5, even Semesan resulted in considerable reduction in the number of smutty plants; and Spergon and copper carbonate, relatively ineffective with head smut, gave considerable control of stripe smut.

[3] Supplied under this name by Dupont Co. Probably thiram and the progenitor of "Arasan" and "Tersan."

Table 4. Comparative Efficacy of Several Popular Fungicidal Dusts and Effect of Various Periods of Post-Treatment Storage on Control of Head Smut, *Ustilago bullata*, in *Elymus canadensis*.

Treatment	Periods of post-treatment storage										Average	
	1 wk.		2 wks.		4 wks.		6 wks.		8 wks.			
	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut	No. Heads	Per Cent Smut
Uninoculated untreated check	708	0.0										
Inoculated untreated check	354	53.6										
Spergon at 2 oz. per bu.	610	46.4	736	29.4	599	29.9	556	28.9	698	33.8	639.8	33.6
Spergon at 4 oz. per bu.	699	29.8	782	18.0	710	24.6	709	23.0	694	36.9	718.8	26.4
Semesan at 2 oz. per bu.	327	66.3	444	72.8	397	70.0	384	73.3	369	69.0	384.2	70.2
Semesan at 4 oz. per bu.	364	71.6	430	69.0	427	72.8	349	56.6	353	62.1	384.6	66.4
New Improved Ceresan at ½ oz. per bu.	755	20.5	660	17.6	722	14.2	755	8.9	610	10.5	700.4	14.3
New Improved Ceresan at 1 oz. per bu.	665	3.5	704	3.3	799	3.3	716	7.6	685	7.6	713.8	5.0
Organic sulphur at 2 oz. per bu.	568	21.4	609	18.9	558	14.2	688	11.0	633	11.1	611.2	15.3
Organic sulphur at 4 oz. per bu.	624	9.9	674	9.7	734	9.2	650	8.3	741	8.9	684.6	9.1
Copper carbonate at 2 oz. per bu.	489	48.6	502	43.9	411	46.0	464	39.0	474	33.3	468.0	42.1
Copper carbonate at 4 oz. per bu.	625	29.6	658	20.9	563	41.8	495	40.6	554	33.0	579.0	33.1
Average	572.6	34.76	619.9	30.35	592.0	32.60	576.6	29.72	581.1	30.62		

TABLE 5. COMPARATIVE EFFICACY OF SEVERAL POPULAR FUNGICIDAL DUSTS AND EFFECT OF VARIOUS PERIODS OF POST-TREATMENT STORAGE ON CONTROL OF STRIPE SMUT, *Ustilago striiformis*, IN *Elymus canadensis*.

Treatment	Periods of post-treatment storage										Average	
	1 wk.		2 wks.		4 wks.		6 wks.		8 wks.			
	No. Plants	Per Cent Smut	No. Plants	Per Cent Smut	No. Plants	Per Cent Smut	No. Plants	Per Cent Smut	No. Plants	Per Cent Smut	No. Plants	Per Cent Smut
Uninoculated untreated check	639	0.0										
Inoculated untreated check	616	31.7										
Spergon at 2 oz. per bu.	552	3.8	604	8.2	608	13.7	592	3.8	567	2.2	584.6	6.3
Spergon at 4 oz. per bu.	625	0.8	616	0.7	672	2.1	634	2.0	660	0.7	641.4	1.2
Semesan at 2 oz. per bu.	822	20.6	786	21.7	814	16.0	746	18.6	721	30.4	777.8	21.4
Semesan at 4 oz. per bu.	844	11.5	500	16.2	582	11.8	598	7.4	628	12.6	630.4	11.9
New Improved Ceresan at ½ oz. per bu.	819	1.4	804	0.3	727	1.2	620	0.1	709	1.3	735.8	0.8
New Improved Ceresan at 1 oz. per bu.	721	0.8	714	0.3	629	0.6	571	0.2	661	0.7	659.2	0.5
Organic sulphur at 2 oz. per bu.	766	4.6	589	4.4	736	2.3	775	2.5	608	1.8	694.8	3.1
Organic sulphur at 4 oz. per bu.	622	2.0	592	1.5	708	1.3	710	1.2	697	6.9	665.9	2.5
Copper carbonate at 2 oz. per bu.	710	6.3	673	6.8	734	2.0	644	3.8	592	5.9	670.6	4.9
Copper carbonate at 4 oz. per bu.	599	4.2	680	2.1	770	5.7	580	2.0	662	2.9	658.2	3.3
Average	708.0	5.60	655.8	6.22	698.0	5.67	647.0	4.16	650.5	6.54		

Studies on the Control of Head Smut by Fungicidal Dusts Applied at Maximum Dosage

In treating small quantities of seed, it is not practical to calculate the exact amount of fungicide for a given amount of seed. In addition, most of the fungicidal dusts found to be effective in controlling head smut in the investigations so far presented are injurious if applied at greater than the recommended dosages. Therefore, for small lots of seed it would be much safer, more convenient, and practical to use a fungicide which could be applied at maximum dosage without injury.[4] In an effort to find such a fungicidal dust, several were selected for study in a preliminary experiment: Arasan, Spergon, New Improved Ceresan, Tersan (Thiosan), and four unnamed preparations furnished by the Boyce Thompson Institute.

The heavily inoculated seed of four species of grasses was shaken with a liberal quantity of fungicide, after which the excess was screened off. The treated seed was sown directly in rows in the field, using three replicates of each treatment. Data were taken on a head count basis.

The results are summarized in Table 6. These results show,

[4] The term "maximum dosage" as used here indicates the amount of fungicidal dust adhering to the seed after the excess has been screened off.

TABLE 6. EFFICACY OF VARIOUS FUNGICIDAL DUSTS IN CONTROL OF HEAD SMUT (*Ustilago bullata*) WHEN APPLIED AT MAXIMUM DOSAGE.

Treatment	Bromus catharticus F 161[a] Per cent smut[b]	Bromus marginatus P 5722 Per cent smut	Elymus canadensis P 788 Per cent smut	Agropyron trachycaulum F 447 Per cent smut
Untreated, uninoculated	10.2	0.2	0.0	1.0
Untreated, inoculated	81.7	100.0	16.1	31.2
Arasan	29.0	0.0	0.6	0.0
Spergon	20.5	86.5	0.3	20.7
New Improved Ceresan	N. S.[c]	N. S.	N. S.	N. S.
Tersan	0.0	0.0	0.0	0.0
249A[d]	81.3	52.8	8.6	5.7
53-501-62[d]	72.1	67.0	6.9	19.8
582[d]	34.3	99.2	9.7	5.8
653[d]	1.5	6.3	1.2	0.0

[a] Accession number - "F" Nos. are those of the senior author; "P" are those of the Soil Conservation Service, Pullman Nursery Unit.
[b] Determined on a head count basis. The "per cent smut" is the average of three replications.
[c] N. S. = no stand.
[d] Unnamed preparations formulated at Boyce Thompson Institute.

first of all, that New Improved Ceresan cannot be used at maximum dosage. In all replications, and with each grass, there was no stand where the seed had been treated with this fungicide. In contrast, Tersan (Thiosan) gave complete control of head smut in all replications and with all the grasses used, and the stands were all good. Arasan, identical with Tersan except for the wetting agent contained in the latter, appears to be slightly inferior to Tersan, especially with *Bromus carthartícus.* In general, Spergon resulted in poor smut control, as did three of the Boyce Thompson products. Of the latter, only Boyce Thompson fungicide 653 controlled head smut to any extent.

In a later experiment on the application of fungicidal dusts at maximum dosage, Tersan and nine new and previously untried fungicides were selected. These fungicides are listed in Table 1, together with the formula of their active ingredients and the name of the manufacturers. Three species were selected for the experiment—*Agropyron trachycaulum, Bromus catharticus,* and *Elymus canadensis,* the latter serving for both head smut and stripe smut.

The seed was treated as described in the previous experiment, stored for 6 weeks, and planted in the field in 6-foot rows using three replications for each treatment. Data were taken after the plants were well headed out; the percentage of smut was computed on a plant basis.

The results for head smut and stripe smut are summarized in Tables 7 and 8, respectively. The data in Table 7 show that 4 per cent phenol mercury chloride and Ceresan M were efficient in head smut control but were so injurious at maximum dosages that little or no stand was obtained. Crag (531) gave good stands but was not effective in smut control. The remaining fungicides tested were, in general, more efficient in head smut control; but their effect on stand differed among the three grass species.

On *Agropyron trachycaulum* and *Elymus canadensis,* Arasan S. F. and Tersan resulted in the greatest increase in stand but not 100 per cent smut control. However, on *E. canadensis,* Dow 9A gave 100 per cent control while improving the stand slightly. With *A. trachycaulum,* Dow 9A, Puratised, Dowicide 2, and Phygon resulted in 100 per cent smut control; and stands were likewise improved. Fermate gave nearly 100 per cent control and improved the stand of grass nearly 200 per cent. With *A. trachycaulum* and *E. canadensis,* the smutted check was sharply reduced in stand so that where the smut was controlled the stand was increased. In contrast, in *Bromus catharticus* the inoculated check, although 100 per cent smutted, was not decreased in stand. There-

TABLE 7. RESULTS OBTAINED WITH MAXIMUM DOSAGE OF 10 FUNGICIDAL DUSTS FOR CONTROL OF HEAD SMUT (*Ustilago bullata*) ON 3 FORAGE GRASSES.

Treatment	A. trachycaulum		B. catharticus		E. canadensis	
	Per cent stand[a]	Per cent smut	Per cent stand	Per cent smut	Per cent stand	Per cent smut
Uninoculated untreated check	409.8	0.0	98.9	0.0	235.0	2.2
Inoculated untreated check	100.0	45.1	100.0	100.0	100.0	90.0
4% phenyl mercury chloride	0.0	-----	0.6	0.0	5.0	0.0
Dow 9A	208.3	1.1	14.6	0.0	161.0	7.1
Ceresan M	45.1	0.0	2.1	0.0	10.0	0.0
Crag (531)	220.3	14.6	75.4	29.6	245.0	61.2
Tersan	360.9	5.6	82.6	0.0	266.5	11.8
Arasan S. F.	366.1	3.5	78.2	0.0	268.5	14.3
Puratised	263.1	0.0	53.2	1.9	-----	-----
Dowicide 2 (F-800)	157.9	0.0	22.8	0.0	-----	-----
Phygon	105.3	0.0	23.9	0.0	-----	-----
Fermate	293.2	2.5	77.2	42.0	-----	-----

[a] Average of three replications, expressed in percentage of inoculated check.

fore, smut control did not result in increased stands. In fact, all of the treatments decreased stands to a greater or lesser degree. Tersan and Arasan S. F. decreased stands the least, while giving 100 per cent smut control. Dow 9A, Puratised, Dowicide 2, and Phygon were quite injurious but resulted in very effective smut control. Fermate resulted in poor smut control on *B. catharticus*.

The data in Table 8 show that the 4 per cent phenyl mercury chloride and Ceresan M reduced the percentage of stripe smut effectively but were very injurious, so that poor stands resulted. Dow 9A reduced stands by approximately 50 per cent and gave in-

TABLE 8. SUMMARY OF RESULTS OBTAINED WITH VARIOUS FUNGICIDAL DUSTS IN CONTROL OF STRIPE SMUT ON *Elymus canadensis*.

Treatment	Per cent stand[a]	Per cent smut
Uninoculated, untreated	67.2	2.5
Inoculated, untreated	100.0	17.2
4% phenol mercury chloride	5.7	0.0
Dow 9A	50.5	15.7
Ceresan M	20.0	2.6
Crag (531)	83.8	7.4
Tersan	87.2	3.9
Arasan S. F.	87.9	7.8

[a] Average of three replications, expressed in percentage of inoculated check.

effective smut control as well. Crag, Tersan, and Arasan S. F. gave the best stands but did not control the smut effectively. In contrast to the stand data on *Elymus canadensis* in Table 7, the data in Table 8 show that all treatments reduced stands somewhat over that of the inoculated untreated control. This is probably because heavy stripe smut inoculation caused no reduction in stand whereas head smut did.

DISCUSSION

The foregoing data show that head smut (*Ustilago bullata*) and stripe smut (*U. striiformis*) are readily controlled by seed treatment practices. However, no one fungicide proved to be consistently and equally efficacious for all grasses, at all dosages, or under all conditions of treatment.

The comparative inefficacy of copper dusts applied to grass seeds for control of smuts is reminiscent of similar results obtained with oats and barley by other investigators. In his experiments on the control of loose smut of oats (*Ustilago avenae*), Rivier (17) obtained very poor control with copper chloride, copper sulfate, and basic copper carbonate. Güssow and Conners (10) state that copper carbonate has not given satisfactory control of covered smut of barley (*U. hordei*), loose smut of oats or covered smut of oats (*U. kolleri*). Greaney and Wallace (9) obtained only partial control of the same smuts, using Bordeaux mixture. Fromme (7) likewise found that copper carbonate was ineffective in the control of loose and covered smuts of oats, except where the hulless varieties were concerned. Other instances could be cited. Likewise, the organic mercury dusts have proved to be as highly effective in controlling head smut and stripe smut of grasses as they are in the control of cereals smuts. Very likely the superiority of the organic mercury dusts is due to their volatility. The smut spores or dormant mycelium under the hull of oats and barley and grasses are protected from the action of the non-volatile copper carbonate and other copper-containing dusts.

The high degree of efficiency of tetramethyl thiuramdisulfide in the control of head smut and stripe smut of grasses is encouraging. It seems to be especially adapted to treating small lots of seed where the comparative cost is not particularly important and it is not feasible to calculate dosages. Even when used at maximum dosage, the resulting stands of slender wheatgrass and Canada wild-rye were more than 300 per cent better than were those of the untreated, inoculated (with *Ustilago bullata*) checks. There were some inconsistencies (as with *Bromus catharticus*), but in

general tetramethyl thiuramdisulfide under the proprietary names Arasan, Arasan S.F., and Tersan has proved highly satisfactory in the control of head smut and has given improved stands. This is quite in contrast with the results of Leukel (14) who found Arasan to be ineffective in the control of covered smut of oats, whether in naturally infected or artificially inoculated seed.

Another organic sulfur compound which merits further trials as a seed treatment chemical is ferric dimethyl dithiocarbamate. In the present experiments this was used under the proprietary name of "Fermate" and gave nearly 100 per cent smut control in slender wheatgrass as well as markedly improved stands (nearly 200 per cent). In the case of rescue grass (*Bromus catharticus*), however, the results were not so encouraging.

In this connection it should be emphasized that the improvement of stands as discussed in the present results is with reference to stands obtained from the untreated inoculated seed, and therefore reflects the effect of heavy smut inoculation on the resulting stands. It thus appears probable that, at least in some cases, seedlings from heavily smutted seed are predisposed to other sinister factors in their environment. Hanson (11) found that wheat plants from seed inoculated with *Tilletia caries* (D.C.) Tul. and *T. foetida* (Wallr.) Liro were significantly predisposed to seedling blight and foot rot. Brandwein (1) likewise noted marked reduction in the emergence and vigor of seedlings of oats from seed inoculated with covered smut (*Ustilago kolleri*), even when so-called resistant varieties were concerned. Stevens (19) observed a marked reduction in stands of Markton and Idamine oats when the seeds had been heavily inoculated ("blackened") with a mixture of *U. kolleri* and *U. avenae*.

The data obtained in the present experiments also indicate that grass seed may be treated at least 8 weeks in advance of seeding, without adversely affecting smut control or vitality of the seed, even when volatile organic mercurials are used. Brett and Dillon Weston (2) found that seed of wheat, oats, and barley suffered no loss of vitality even if stored as much as a year or more after treatment with volatile organic mercury dusts, provided the seed had a high germination potential to start with, had average moisture content, was treated according to recommendations, and was stored under satisfactory conditions (low humidity, relatively constant temperature, and in unclosed containers). Koehler (13) found that not only could cereal seed (wheat, oats, and barley) be stored after treatment with volatile organic mercurials, but actually the dosage rate could be reduced by half or one-fourth, with the same protection. Whether or not these

results are applicable to grass seed should be investigated, but theoretically, grass seed should respond essentially the same as do the cereals whose seeds do not have naked caryopses.

SUMMARY

The results are given of several years' experiments in the control of head smut and, to a lesser extent stripe smut, of certain forage grasses by seed treatment.

In general, copper carbonate, copper sulphate, cuprocide, Formacide, and Semesan used as seed protectant dusts did not control head smut in slender wheatgrass, Canada wild-rye, mountain brome, and rescue grass.

Much less than 1 hour of soaking the seed in 1:320 formaldehyde did not entirely control head smut, but 1 hour or more did. At least slender wheatgrass and Canada wild-rye seed can withstand as much as 4 hours formaldehyde steep with little or no apparent injury, and it seems probable that other grass seeds of similar morphology could likewise.

In general, organic mercury dusts were highly effective in controlling head smut. New Improved Ceresan and 2 per cent Ceresan gave excellent control; but overdosage resulted in seed injury and reduced stands. Semesan gave much improved stands but virtually no smut control in some cases and actually an increase in percentage of smut in other cases. This is attributed to the protection given by Semesan against seed decay or early damping off, to which smut infected seed apparently is predisposed.

Certain organic sulphur dusts proved highly effective. Arasan, Arasan S.F., and Tersan (all having tetramethyl thiuramdisulfide as active ingredient, but with wetting agent in the latter two) gave excellent head smut control and could be used at maximum dosage (i.e., all that can be retained by dry seed) with little or no seed injury. Fermate gave nearly 100 per cent head smut control and nearly 200 per cent improvement in stands (over the untreated, inoculated check).

Some other newer fungicides appear promising and should be given further trials as grass and cereal seed disinfectants. On Canada wild-rye and slender wheatgrass, Dow 9A, Puratised, Dowicide 2, and Phygon resulted in complete smut control and some improvement in stands, even at maximum dosage and 6 weeks' storage prior to seeding.

In treating small lots of grass seed, where it is impracticable to calculate dosages, perhaps the most generally applicable protectants, from the standpoint of smut control and stand improvement,

are Arasan S. F. and Tersan (Thiosan), because they have the added advantage of utility at maximum dosage.

The results indicate that grass seed (at least slender wheatgrass, Canada wild-rye, and mountain brome) can be stored at least 8 weeks after treatment for smut control, even with volatile mercurials, without influence on the degree of control or vitality of the seed.

Stripe smut appeared to be more vulnerable to seed treatment fungicides than did head smut. Besides the more effective mercurials and the organic sulfur compounds, such generally inferior (for head smut) materials as Semesan, Spergon, and copper carbonate gave effective control.

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